CLAIMS

1. A method of constructing a cardiac map of a heart having a heart cycle comprising:

(a) bringing an invasive probe into contact with a location on a wall of the heart;

(b) determining, at at least two different phases of the heart cycle, a position of the invasive probe;

(c) determining a local non-electrical physiological value at the location;

(d) repeating (a)-(c) for a plurality of locations of the heart; and

(e) combining the positions to form a time-dependent map of at least a portion of the heart.

2. A method according to claim 1, comprising:

(f) determining at least one local relationship between changes in positions of the invasive probe and a determined local non-electrical physiological value.

3. A method of constructing a cardiac map of a heart having a heart cycle comprising:

(a) bringing an invasive probe into contact with a location on a wall of the heart;

(b) determining a position of the invasive probe;

(c) determining a local non-electrical physiological value at the location at a plurality of different phases of the heart cycle;

(d) repeating (a)-(c) for a plurality of locations of the heart; and

(e) combining the positions to form a map of at least a portion of the heart.

4. A method according to claim 3, comprising determining at least a second position of the invasive probe at a phase at which the local non-electrical value is found, which position is different from the position determined in (b).

5. A method according to claim 4, comprising determining at least one local relationship between changes in positions of the invasive probe and determined local non-electrical physiological values.

6. A method according to any of claims 1-5, comprising determining a trajectory of the

probe as a function of the cardiac cycle.

7. A method according to claim 6, comprising analyzing the trajectory.

8. A method according to any of claims 1-7, wherein the local physiological value is determined using a sensor external to the probe.

9. A method according to claim 8, wherein the sensor is external to a body which comprises the heart.

10. A method according to any of claims 1-7, wherein the local physiological value is determined using a sensor in the invasive probe.

11. A method according to any of claims 1-10, wherein the local physiological value is determined at substantially the same time as the position of the invasive probe.

12. A method according to any of claims 1-11, wherein the map comprises a plurality of maps, each of which corresponds to a different phase of the cycle of the heart.

13. A method according to any of claims 1-11, wherein the map comprises a difference map between two maps, each of which corresponds to a different phase of the cycle of the heart.

14. A method according to any of claims 1-13, wherein the local physiological value comprises a chemical concentration.

15. A method according to any of claims 1-14, wherein the local physiological value comprises a thickness of the heart at the location.

16. A method according to claim 15, wherein the thickness of the heart is determined using an ultrasonic transducer mounted on the invasive probe.

17. A method according to any of claims 15-16, comprising, determining a reaction of the heart to an activation signal by analyzing changes in the thickness of the heart.

18. A method according to any of claims 1-17, wherein the local physiological value comprises a measure of a perfusion at the location.

19. A method according to any of claims 1-18, wherein the local physiological value comprises a measure of work performed at the location.

20. A method according to any of claims 1-19, comprising determining a local electrical activity at each of the plurality of locations of the heart.

21. A method according to claim 20, wherein the electrical activity comprises a local electrogram.

22. A method according to claim 20 or claim 21, wherein the electrical activity comprises a local activation time.

23. A method according to claim any of claims 20-22, wherein the electrical activity comprises a local plateau duration of heart tissue at the location.

24. A method according to any of claims 20-23, wherein the electrical activity comprises a peak-to-peak value of a local electrogram.

25. A method according to any of claims 1-24, comprising, determining a local change in the geometry of the heart.

26. A method according to claim 25, wherein the local change comprises a change in a size of an area surrounding the location.

27. A method according to claim 25, wherein the local change comprises a warp of an area surrounding the location.

28. A method according to claim 25, wherein the local change comprises a change in a local radius of the heart at the location.

29. A method according to any of claims 25-28, comprising, determining an intra-cardiac pressure of the heart.

30. A method according to claim 28 or claim 29, comprising determining a relative tension at the location.

31. A method according to claim 30, wherein the relative tension is determined using Laplace's law.

32. A method according to any of claims 25-29, comprising determining an absolute tension at the location.

33. A method according to any of claims 1-32, comprising determining a movement of the location on the heart wall relative to the movement of neighboring locations.

34. A method according to any of claims 1-33, comprising determining the activity of the heart at the location.

35. A method according to claim 34, wherein determining the activity comprises determining a relative motion profile of the location on the heart wall relative to neighboring locations.

36. A method according to claim 34, wherein determining the activity comprises determining a motion profile of the heart at the location.

37. A method according to any of claims 1-36, comprising monitoring stability of the contact between the invasive probe and the heart.

38. A method according to claim 37, wherein monitoring comprises monitoring the stability of the contact between the probe and the heart based on the motion profile.

39. A method according to any of claims 37-38, wherein monitoring comprises detecting changes in the motion profile for different heart cycles.

40. A method according to any of claims 37-39, wherein monitoring comprises detecting differences in positions of the probe at the same phase for different heart cycles.

41. A method according to any of claims 37-40, wherein monitoring comprises detecting changes in a locally measured impedance of the invasive probe to a ground.

42. A method according to any of claims 37-41, wherein monitoring comprises detecting artifacts in a locally determined electrogram.

43. A method according to any of claims 1-42, comprising reconstructing a surface of a portion of the heart.

44. A method according to any of claims 1-43, comprising binning local information according to characteristics of the cycle of the heart.

45. A method according to claim 44, wherein the characteristics comprise a heart rate.

46. A method according to claim 44 or claim 45, wherein the characteristics comprise a morphology of an ECG of the heart.

47. A method according to claim 46, wherein the ECG is a local electrogram

48. A method according to any of claims 44-47, comprising separately combining the information in each bin into a map.

49. A method according to claim 48, comprising determining differences between the

maps.

50. A method according to any of claims 1-49, wherein the positions of the invasive probe are positions relative to a reference location.

51. A method according to claim 50, wherein the reference location is a predetermined portion of the heart.

52. A method according to any of claims 50-51, wherein a position of the reference is determined using a position sensor.

53. A method according to any of claims 50-52, comprising periodically determining a position of the reference location.

54. A method according to claim 53, wherein the position of the reference location is acquired at the same phase in different cardiac cycles.

55. A method according to any of claims 1-54, wherein the invasive probe is located in a coronary vein or artery.

56. A method according to any of claims 1-54, wherein the invasive probe is located outside a blood vessel.

57. A method according to any of claims 1-56, wherein local information is averaged over a plurality of cycles.

58. A method of determining the effect of a treatment comprising:

constructing a first map of a heart according to any of claims 1-56, prior to the treatment;

constructing a second map of the heart, after the treatment; and

comparing the first and second maps to diagnose the effect of the treatment.

59. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to determine underutilized portions of the heart.

60. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to select a procedure for treating the heart.

61. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to determine optimization possibilities in the heart.

62. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to determine underperfused portions of the heart.

63. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to determine over-stressed portions of the heart.

64. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to determine local pathologies in the heart.

65. A method comprising:
constructing a map of a heart according to any of claims 1-56; and
analyzing the map to assess the viability of portions of the heart.

66. A method of determining the effect of a change in activation of a heart, comprising:
constructing a first map of a heart according to any of claims 1-56, prior to the change;
constructing a second map of the heart, after the change; and
comparing the first and second maps to diagnose the effect of the change in activation.

67. A method of determining the effect of a change in activation of a heart, comprising:
constructing a first map of a heart according to any of claims 1-56, prior to the change;
constructing a second map of the heart, after the change; and
constructing a second map of the heart; and
comparing the first and second maps, wherein the two maps are acquired in parallel by acquiring local information at a location over several cardiac cycles, wherein the activation changes during the several cardiac cycles.

68. A method of assessing viability comprising:
constructing a first map of a heart according to any of claims 1-56, prior to a change in activation of the heart;
constructing a second map of the heart, after the change; and
comparing the first and second maps to assess the viability of portions of the heart.

69. A method according to any of claims 66-68, wherein changing the activation comprises changing a pacing of the heart.

70. A method according to any of claims 66-68, wherein changing the activation comprises subjecting the heart to chemical stress.

71. A method according to any of claims 66-68, wherein changing the activation comprises subjecting the heart to physiological stress.

72. A method according to any of claims 1-71, wherein the heart is artificially paced.

73. A method of cardiac shaping comprising:
generating a map of a heart;
choosing a portion of the heart having a certain amount of muscle tissue thereat; and
determining a pacing regime for changing the workload of the portion.

74. A method according to claim 73, comprising pacing the heart using the determined

pacing regime.

75. A method according to claim 74, comprising:
waiting a period of time;
then determining the effect of the pacing regime; and
repeating choosing, determining and pacing if a desired effect is not reached.

76. A method according to any of claims 73-75, wherein the workload of the portion is increased in order to increase the amount of muscle tissue therein.

77. A method according to any of claims 73-75, wherein the workload of the portion is decreased in order to decrease the amount of muscle tissue thereat.

78. A method according to any of claims 73-77, wherein the workload is changed by changing an activation time of the portion.

79. A method according to any of claims 73-78, wherein the map includes electrical activation information.

80. A method according to any of claims 73-79, wherein the map includes mechanical activation information.

81. A method of determining an optimal location for implanting a pacemaker electrode comprising:
(a) pacing a heart from a first location;
(b) determining a cardiac parameter associated with pacing at the location; and
(c) repeating (a) and (b) for a second location; and
(d) selecting an optimal location based on the determined values for the cardiac parameters.

82. A method according to 81, comprising:
(e) implanting the electrode at the location for which the cardiac parameter is optimal.

83. A method according to any of claims 81-82, wherein pacing a heart comprises bringing an invasive probe having an electrode to a first location and electrifying the electrode with a pacing current.

84. A method according to any of claims 81-83, wherein the cardiac parameter comprises stroke volume.

85. A method according to any of claims 81- 84, wherein the cardiac parameter comprises intra-cardiac pressure.

86. A method according to any of claims 81-85, wherein determining the cardiac parameter comprises measuring the cardiac parameter using an invasive probe.

87. A method of determining a regime for pacing a heart, comprising:

(a) determining a local physiological value at a plurality of locations in the heart; and

(b) determining a pacing regime which changes a distribution of the physiological value in a desired manner.

88. A method according to claim 87, wherein the distribution comprises a temporal distribution.

89. A method according to any of claims 87-88, wherein the distribution comprises a spatial distribution.

90. A method according to any of claims 87-88, comprising pacing the heart using the determined pacing regime.

91. A method according to any of claims 87-90, wherein changing the distribution comprises maintaining physiological values within a given range.

92. A method according to claim 91, wherein the range comprises a locally determined

range.

93. A method according to any of claims 91-92, wherein the range comprises a phase dependent range, whereby a different range is preferred for each phase of a cardiac cycle.

94. A method according to any of claims 91-93, wherein the range comprises an activation dependent range, whereby a different range is preferred for each activation profile of the heart.

95. A method according to claim 94, wherein different heart rates have different ranges.

96. A method according to claim 94, wherein different arrhythmia states have different ranges.

97. A method according to any of claims 87-96, wherein the physiological values are determined substantially simultaneously.

98. A method according to any of claims 87-97, wherein the physiological value comprises perfusion.

99. A method according to any of claims 87-98, wherein the physiological value comprises stress.

100. A method according to any of claims 87-99, wherein the physiological value comprises plateau duration.

101. A method of determining a preferred pacing regime, comprising:

generating a map of the heart; and

determining, using the map, a preferred pacing regime for a heart which is optimal with respect to a physiological variable.

102. A method according to claim 101, comprising pacing the heart using the preferred pacing regime.

103. A method according to any of claims 101-102, wherein the map comprises an electrical map.

104. A method according to claim 103, wherein determining a preferred pacing regime comprises generating a map of the activation profile of the heart.

105. A method according to any of claims 101-103, wherein the map comprises a mechanical map.

106. A method according to claim 105, wherein determining a preferred pacing regime comprises generating a map of the reaction profile of the heart.

107. A method according to any of claims 101-106, comprising analyzing an activation map or a reaction map of the heart to determine portions of the heart which are under-utilized due to an existing activation profile of the heart.

108. A method according to any of claims 101-107, wherein pacing is initiated by implanting at least one pacemaker electrode in the heart.

109. A method according to claim 108, wherein the at least one pacemaker electrode comprises a plurality of individual electrodes, each attached to a different portion of the heart.

110. A method according to any of claims 101-109, wherein pacing is initiated by changing the electrification of a plurality of previously implanted pacemaker electrodes.

111. A method according to any of claims 101-110, wherein the physiological variable comprises a stroke volume.

112. A method according to any of claims 101-110, wherein the physiological variable comprises a ventricular pressure profile.

113. A method of pacing comprising:

(a) pacing a heart using a first pacing scheme; and

(b) changing the pacing scheme to a second pacing scheme, wherein the change in pacing is not directly related to a sensed or predicted arrhythmia, fibrillation or cardiac output demand in the heart.

114. A method according to claim 113, wherein each of the pacing regimes optimizes the utilization of different portions of the heart.

115. A method according to claim 113 or claim 114, wherein the changing of the pacing regimes temporally distributes workload between different portions of the heart.

116. A pacemaker which performs a least one method according to any of claims 87-115.

117. A pacemaker comprising:

a plurality of electrodes;

a source of electricity for electrifying the electrodes; and

a controller which changes the electrification of the electrodes in response to a plurality of values of local information of a heart, measured at different locations, to achieve an optimization of a cardiac parameter of the heart.

118. A pacemaker according to claim 117, wherein the local information is measured using the electrodes.

119. A pacemaker according to any of claims 117-118, wherein the local information is measured using a sensor.

120. A pacemaker comprising:

a plurality of electrodes;

a source of electricity for electrifying the electrodes; and

a controller which changes the electrification of the electrodes in response to a stored map of values of local information of a heart at different locations, to achieve an optimization

of a cardiac parameter of the heart.

121. A pacemaker according to any of claims 117-120, wherein the local information comprises a local activation time.

122. A pacemaker according to any of claims 117-121, wherein the local information comprises a local plateau duration.

123. A pacemaker according to any of claims 117-122, wherein the local information comprises local physiological values.

124. A pacemaker according to any of claims 117-123, wherein the local information comprises phase dependent local positions.

125. A pacemaker according to any of claims 117-124, wherein the cardiac parameter comprises a stroke volume.

126. A pacemaker according to any of claims 117-125, wherein the cardiac parameter is measured by the pacemaker.

127. A pacemaker according to any of claims 117-126, wherein the cardiac parameter comprises an intra-cardiac pressure.

128. A method of detecting structural anomalies in a heart, comprising:

(a) bringing an invasive probe into contact with a location on a wall of the heart;

(b) determining a position of the invasive probe;

(c) repeating (a)-(b) for a plurality of locations on the wall;

(d) combining the positions to form a time-dependent map of at least a portion of the heart; and

(e) analyzing the map to determine structural anomalies in the heart.

129. A method according to claim 128, wherein the structural anomaly is an insipid

aneurysm.

130. A method according to any of claims 128-129, comprising repeating (b) at least a second time, at the same location and at a different phase of the cardiac cycle than (b).

131. A method of adding a conductive pathway in a heart between a first segment of the heart and a second segment of the heart, comprising:

generating a mechanical map of the heart;

providing an activation conduction device having a distal end and a proximal end;

electrically connecting the distal end of the device to the first segment; and

electrically connecting the proximal end of the device to the second segment.

132. A conductive device for creating conductive pathways in the heart, comprising:

a first lead adapted for electrical connection to a first portion of the heart;

a second lead adapted for electrical connection to a second portion of the heart;

a capacitor for storing electrical charge generated at the first portion of the heart and for discharging the electrical charge at the second portion of the heart.

133. A method of viewing a map, comprising:

providing a map of local information of a heart; and

overlaying a medical image on the map.

134. A method according to claim 133, wherein the medical image is an angiogram.

135. A method according to any of claims 133-134, wherein the medical image is a three-dimensional image.

136. A method according to any of claims 133-134, wherein the map contains both spatial and temporal information.

137. A method of diagnosis comprising:

generating a map of a heart; and

correlating the map with a library of maps.

138. A method according to claim 137, comprising diagnosing the condition of the heart based on the correlation.

139. A method of analysis, comprising:
generating a map of electrical activation of a heart;
generating a map of mechanical activation of the heart; and
determining local relationships between the local electrical activation and mechanical activation.

140. A method according to claim 139, wherein the mechanical activation comprises a profile of movement.

141. A method according to any of claims 139-140, wherein the electrical activation comprises an activation time.

142. Apparatus adapted to generate a map in accordance with any of claims 1-56.

143. Apparatus according to claim 142, comprising a display adapted to display the map.

144. Apparatus comprising:
a memory having a plurality of maps stored therein; and
a correlator which correlates an input map with the plurality of maps.